FDTD Channel Modelling with Time Domain Huygens’ Technique

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Outline

- Introduction
- Modelling of large electromagnetic problems
- Propagation Scenario
- Time Domain Huygens' Technique
- Results
- Conclusions

Introduction

- Millimetre wave receive much attention recently
- Particular interest for 60 GHz band
- Suitable for indoors propagation
- Short propagation distance
  → secure personal networks
- How do we model a high rate data link?

Modelling large electromagnetic problems

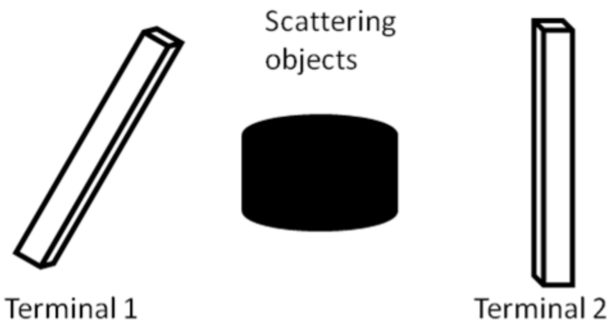
- Indoor wireless transmission systems are hard to predict as they depend on operating frequency and the environment
- Techniques used:
  - Statistical models
  - Ray tracing
  - Time domain integral equations
- Other numerical techniques exist:

  TLM, MoM, FDTD

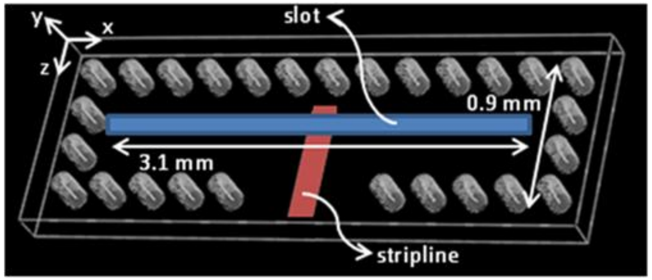
Modelling large electromagnetic problems

- Finite-Difference Time Domain (FDTD) technique
- Maxwell’s equations discretised in space and time
- FDTD is accurate, flexible, can model inhomogeneous materials and even frequency dependent materials
- However, FDTD typically requires a very fine mesh to model fine details
- Problematic when the environment is large with several wavelengths

Propagation Scenario

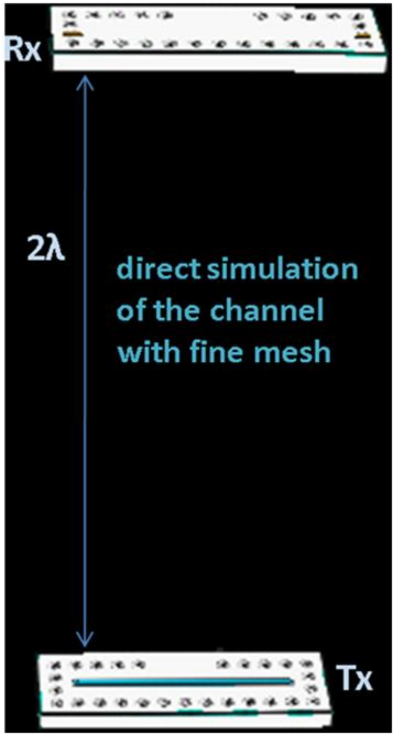


- Antenna Element



60 GHz CBS antenna geometry:
slot length=3.1mm
slot width=0.1mm
cavity width=0.9mm
cavity length=3.6mm

- Propagation Channel



60 GHz Channel Model:
Tx and Rx antennas are facing each other
2λ(10mm) separation between them

Time Domain Huygens' Technique (TDH)

- Run time decreased by dividing the problem domain into sub-domains
- This is achieved by applying Huygens' Principle in the time domain
- The fields are calculated on the chosen Huygens' surface for one sub-domain and these are used as an input for the following sub-domain
- Technique applied in time domain

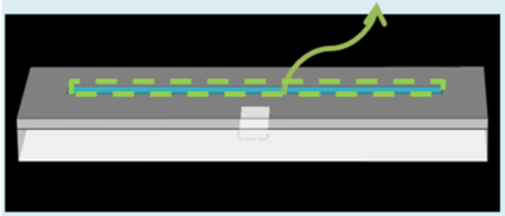
  →more suitable for **large bandwidth scenarios**

  and also **preserves delay profile information** in a direct manner

Time Domain Huygens' Technique

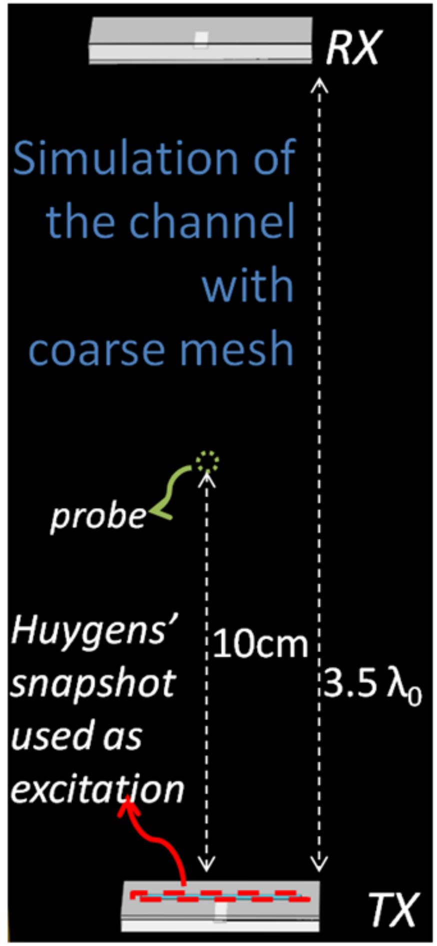
Step 1

Huygens' snapshot

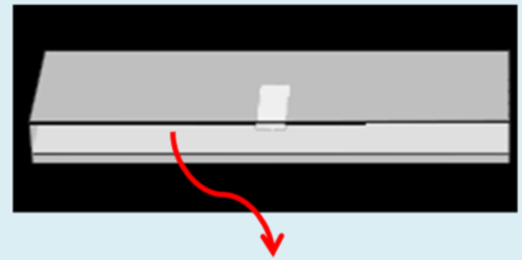


Simulation of the transmit antenna

Step 2



Step 3



Huygens' snapshot used as excitation

Simulation of the receive antenna

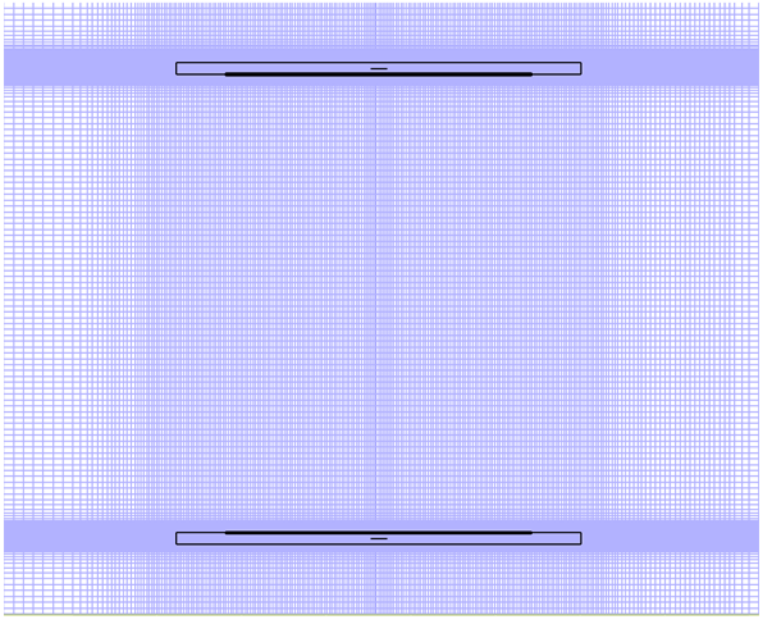
Time Domain Huygens' Technique

- *<u>Step 1</u>*: Only the transmit antenna is simulated in isolation using a fine mesh. At each time step of the simulation, the tangential E&H fields on the slot are recorded. The size of the computational domain is small, in this case 9x6.5x6.6mm.

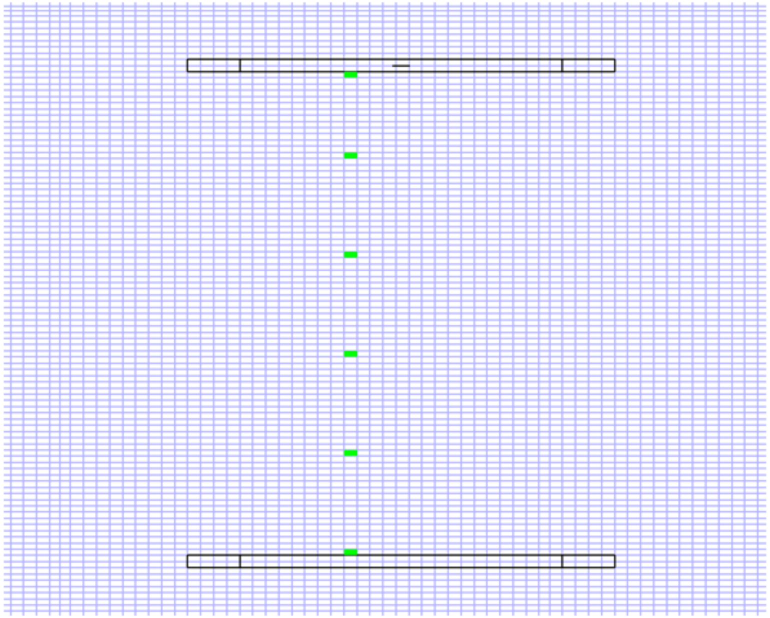
- *<u>Step 2</u>*: The full structure is modelled but with a mesh which is much coarser than would be needed in a direct FDTD simulation. The details of the antenna do not need to be accurately represented. The Huygens' snapshot, produced in step 1 will be used for excitation.

- *<u>Step 3</u>*: The receive antenna is modelled in isolation using a fine mesh and is excited at the slot by the second Huygens' snapshot.

Time Domain Huygens' Technique



Mesh for the direct simulations

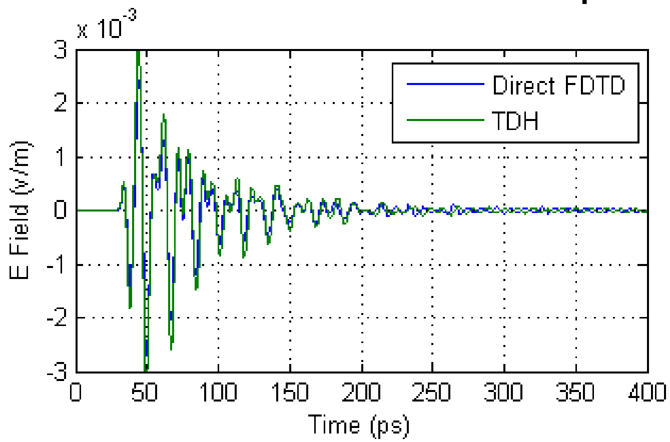


Mesh for stage 2 of TDH method

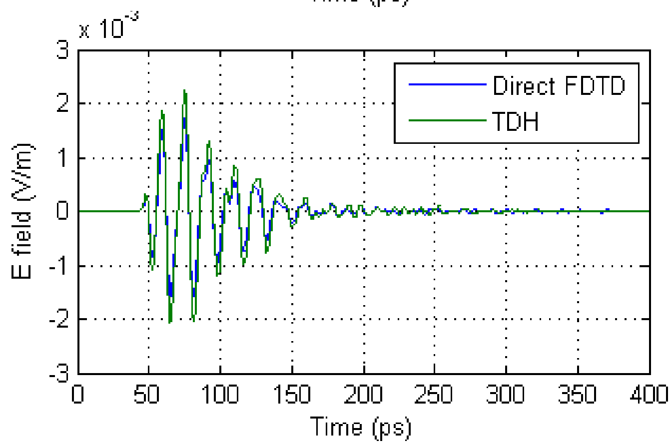
Time domain results

Verification of Huygens' technique at step 2 with E field variations at two different probes

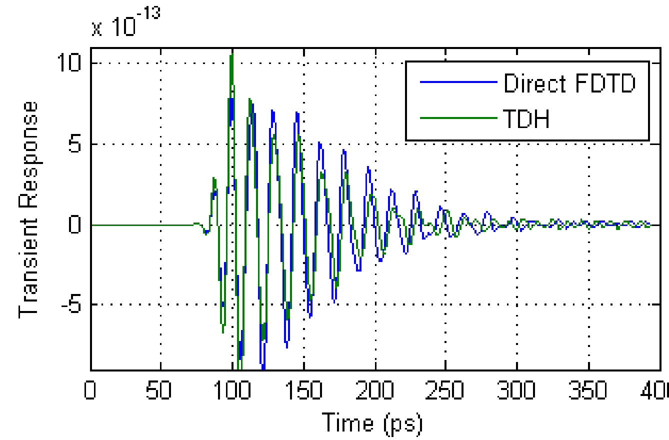
Probe 1



Probe 2

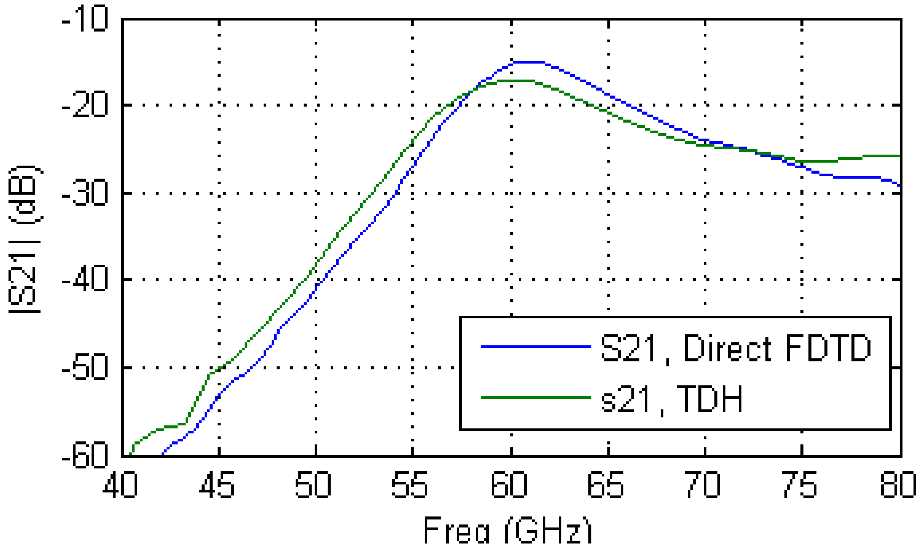


Transient response on receiving antenna at step 3



- Results using TDH are almost identical to those produced using direct FDTD
- It can be seen that both in in phase although TDH results are somewhat higher

Frequency domain results



- Signal transmitted to the receiving antenna
- TDH technique and direct FDTD simulation are in good agreement
- Underestimation of 2.1 dB at 60 GHz

Computing resources

- In total:
  - all three steps of the TDH run take 4h 44 mn
  - the direct simulation takes 2h 38 mn
  - → this is a **56% saving**

- Total run time with TDH will be reduced to 1h 55 mn for each channel simulation (32% of direct run) once the first step is simulated

- Step 2 takes 37 mn and step 3 takes 1h 18 mn on an Intel Xeon X5670 processor

- In a more complicated environment with other objects in the vicinity of the two antennas, an even larger time improvement may be expected

Conclusions

- A method of analysing a complete short-range, high-speed communications link by means of FDTD and TDH techniques has been demonstrated
- The technique is shown to be very powerful for modelling inhomogeneous media and small objects and details
- An improvement in computer resources of 56% was achieved
- It is expected that, for more complicated scenarios, the saving in computer resources may be even greater
- This approach has great potential for large bandwidth scenarios and can be applied in more realistic channel modelling
- The time domain Huygens' technique is very promising for the modelling of large electromagnetic problems and should have many applications

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